International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 04 | Apr -2017 www.irjet.net p-ISSN: 2395-0072

Hydrologic Computations of SCS-CN, Rational, Area velocity and Tc Methods for Quantifying the Forest Surface Water Runoff - A case study in Sirumalai hill environs of Sathiyar Reservoir, Madurai, Tamil Nadu, India

K.Chandramohan[1], R.Vijaya[2]
[1] Ph.D Research Scholar,
[2] Assistant Professor, UGC-Human Resource Development Centre,
Madurai Kamaraj University, Madurai, Tamil Nadu, India.

Abstract - *Majority of surface water flow data are needed for engineers, planers, policy makers and other environmental developers. In this regard, surface water quantification is an essential study. Surface water measurement can be done by various methods in order to know the surplus or shortage of water availability and hence the hydrologic calculation is an important factor in the surface water study. Surface runoff is the water flows from the elevated area to the low lying area and it makes the land as wetland in which it flows. The main objective of the study is to quantify the surface water in Sirumalai hill environs of Sathiyar Reservoir, Madurai, Tamil Nadu using various mathematical calculations and methods. Several measuring techniques which involve mathematical models and equations are available to find the surface water volume and flow rate. Here, the rational method which is followed worldwide is used to find out the surface water quantity. In this rational method, many parameters like runoff coefficient, intensity of rainfall, area of drainage etc., were adapted. Runoff (RF) calculation was carried out by using potential abstraction, soil Curve Number (CN) and intensity of rainfall, while the runoff value was calculated by Soil Conservation Service (SCS). This research work will clearly deals with two major components of water balance of rainfall intensity and runoff. Field dada collection was carried out for homogeneous micro watersheds of the study area based on the slope and rainfall intensity at the sites using same tools and techniques. Water states were measured by Syman's raingauge meter and Bucket method for water quantification in direct field measuring for rainfall intensity and flow rate respectively. These values are reclassifying and try to extend to find other methods of Thiessen polygon, SCS CN, Rational method of runoff coefficient and Time of Concentration.*

Key Words: *Water balance, Runoff, Coefficient, Hydrologic Calculation, Surface, Runoff, SCS CN, Thiessen polygon, Rational method, Time of Concentration (Tc), Area velocity, Remote Sensing, GIS, GPS …*

1.INTRODUCTION

In general, storm water runoff can be described as the flow of water through rainfall interaction with the land. The calculation of runoff coefficient will vary due to different types of physiographic features like vegetation interception, soil infiltration, slope, geomophological structure etc. The rainfall events can also be varied in a same period. These events produce different runoff volumes and peak discharge. Rational method was developed by Kuichling (1889) to estimate the channel runoff. Water-resources planning typically include identifying alternatives and ranking the alternatives based on specified criteria. The purpose of the hydrologic study using the present techniques is carried out for estimating peak discharges of runoff water. When actual flow data has been transformed into a normal variable by using the logarithmic transformation, then the prediction of runoff value will be easy (Lawrence K. Wang, 2014). The earth surface will be completely soaked when the micro watershed area is fully covered by flood water (Slobodan P. Simonovic 2009) then the surplus was drained into the canals. The Rational Method is widely used to calculate the peak storm water runoff rate for a variety of storm water management applications. If the planners have associated flow data in such situation, engineers use this prediction equations called flood frequency equation to predict the flood value. Mathematical calculation of hydrologic parameters also referred as hydrological models (Kite.G.W and Pietroniro.A, 1996). These mathematical models can be applied to other micro watershed regions to plan the construction of highway, cableway, bridge, electricity, ice cover, or boat house and other constructions cross over the stream and river if the runoff value is known. Water and sediment control practices should be made easy and control measurement should be fixed on more possible places (Haan.C.T. et al 1994).

1.1 Study Area

The study area of Sathiyar sub basin of Sirumalai hill Micro watersheds lies in between 10°14'44" – 10°0'6" North latitudes and between 78°7'25" – 77°59'1" east longitudes, also lying between the Palani hill on the north-western side and Alagar hill on the south-eastern side. The area of Satti aru valley region is the major part of Sirumalai hill which include nearly 28 micro watersheds. Sathiyar reservoir is situated in the Alanganallur block, lying between the Waguthumalai on the western side and Sempatti hill on the eastern boundary. The Figure.1 depicts the clear identification of the study area location. The study area is having 820 stream lines which in the fifth stream order have been started in the exact location of (78°0'38.078"E 10°13'10.231"N) meet point of Micro watersheds M1 and M2. There are 28 micro watersheds present in the Sathiyar reservoir catchment and ayacut area with areal extensions from minimum 1 sqkm to maximum 10 sqkm. 24 micro watersheds are present in the catchment area of Satti Ar river valley region. Water from these watersheds is collected in the Sathiyar reservoir; remaining 4 micro watersheds are present in the lower part (foot hill) of Sathiyar reservoir and these are fully depending upon the surface water source from Sirumalai hill micro watershed runoff. Reservoir's catchment area is 37 Sq.Miles, water spread area of reservoir is 3.61 Sq.Miles, Capacity at FRL* is 56.00 Mcft* and Maximum Flood Discharge is 9705 C\S*. It was constructed in 1965 and its depth is 29 ft.

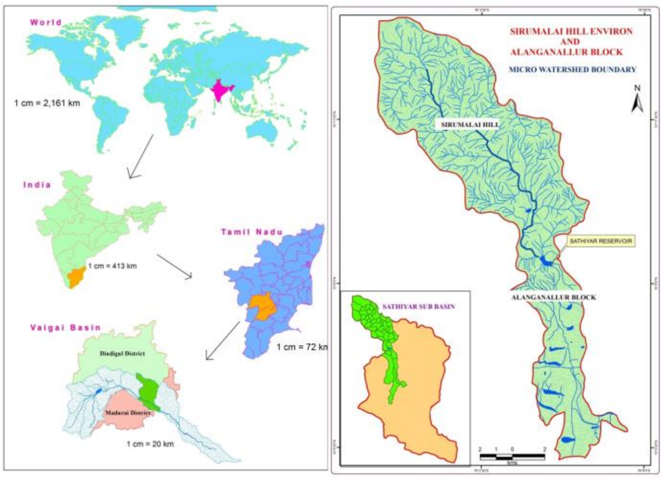

Figure - 1: Location map of Study area

Flood occurred in 1993 was widely acknowledged as largest flood in this study area and this flood has affected Alanganallur agricultural field, Madurai Sellur and Koripalayam settlement region. This information was collected from the local area people living inside the Alanganallur block of micro watershed (M27 A). The study area of part of Sathiyar sub basin is 31037 acre, and then this area sub is divided into catchment area (23527 acre) and Ayacut or cultivated area (7510 acre). The catchment area is three times more when compared with the ayacut area.

**Full Reservoir Level (FRL), million cubic feet (mcft) and cubic meters per second (C/S)*

1.2 Objectives

The objectives of the study are:

- To analyse the mean precipitation over the study area through Thiessen polygon method
- To measure the rainfall intensity by Symon's gauge (Temporary rain gauge) method and runoff flow rate by Bucket method
- To find out the runoff coefficient and peak discharge by SCS-CN and Rational method calculation respectively
- To estimate the time of concentration or travel time for channel flow runoff and area velocity

2. Methodology Tools and Technique

Tools like GPS, rain gauge meter, bucket, rope, stop watch were used for identifying the location and measuring the runoff rate. GIS technique of Thiessen polygon and mathematical calculations of Direct Runoff (SCS-CN method), Runoff Coefficient, Rational method, Surface runoff flow rate, Time of concentration (Tc) of Channel flow, Direct Discharge measurement of Area-velocity method were used in this study.

3. Techniques

In the present study, in order to quantify the amount of surface water of the study area, the GIS and GPS techniques were used for digitization and location with elevation identification respectively and also for Thiessen polygon creating and mapping purposes. The locations were identified in water collecting areas of the end of the first order stream lines which join with another stream order, just before the junction point of another stream line is the suitable place for surface runoff flow rate measurement.

4. Rain gauge meter

Standard rain gauge was developed by George James Symons FRS (1860) who was a British meteorologist (Figure 5.c). The gauge consists of a funnel adapt with cylinder that fits into a container. Cylinder is marked by mm measurement up to 25 mm (0.98 in). Each horizontal line on the cylinder is 0.2 mm (0.007 in) (Lanza.L et al., 2005). In India, this British standard method of **Symon's gauge** is commonly used.

5. Thiessen Polygon Method

Thiessen polygon method is one of the predominant methods for mean precipitation calculation for huge coverage of areal extents in any location. Thiessen polygons have a unique property connected with location of point features but not able to distinguish with orographic features.

If collection of rainfall data from minimum two to more rain gauge stations in different locations, then the mean precipitation value is easy to calculate for large areal extents. The catchment rain gauge station connected boundary equally bisected by the connecting boundary (Figure 2). By using the isohyetal maps, it is assumed that the maximum rainfall observed in a given storm is approximately equal to the maximum rainfall that occurred (Arved J.Raudkivi, 1979).

6. Bucket method (Runoff flow measurement)

So many methods are available for runoff flow measurement like Ball flow, Weir, Bucket method etc,. The bucket method is suitable for this study area. The outlet segment of the first order stream line's end place (just before the junction point of another stream or river) has been chosen for water collection point. The sample location and it's latitudinal and longitudinal values are presented in Table 2. Flow of water in an irrigation channel can be used as a measuring unit (Darbral P.P et al 2014). Main part of the research in field investigations and site selections are based on water measuring techniques. The site selection has been pre-scheduled earlier to the start of rainfall because it will be easy to construct a temporary step slope based on the bucket height for water collections (Trimmer .W.L, 1994). Distance is measured from the starting point of stream line to temporary step slopping point. Stream flow can be concentrated for more accurate measurement meanwhile the rainfall measured is by Symon's gauge.

7. Result and Discussion

The rainfall is not evenly distributed in the entire study area at the same time, but in all the micro watersheds of entire study area, rain fall has occurred in particular time interval. Specific time and place will depend on both the direction of the advected air mass (Meteorological Office 1962; Barry and Chorley 1987 and Millán M.M et al 2005). The results of this work contained the data collected from four field work days and the resulting maps and photographs are shown.

8. Runoff calculation

The field observation of Sathiyar Dam which has three hours of continuous rainfall showed that the rainfall was 10 mm in 28/07/2016 midnight (11.00 pm to 2.00 am) to 29/07/2016. Through field identification it is measured that the rainfall occurred is approximately from one to one – and – half square kilometre radius area of micro watersheds are M35, M36, M37 and M38 for Sembatti malai and Vaguthumalai area (see Figure 3) and also the Sirumalai Hill Micro watersheds of M25 and M3. Mean while there is no improvement in water level rise in the inside of the dam area because more rain fall occurred only in the nearby hill areas and not in the micro watersheds of the Sirumalai hill catchment area. If the rainfall occurred in this Sirumalai area, then the water level in the Dam will be increased.

9. Drainage Area

Rational method (David B. Thompson, 2006) can be applied for identifying the hydraulic design of watersheds of 20 square miles or more with 100 or more subareas). Kerby (1959) defined flow length as the straight-line distance from the most distant point of a basin to its outlet, measured parallel to the surface slope. Drainage area of stream line is calculated as multiplied by length and width of the stream line (Figure 5.d). A headwater stream with no tributaries is a first order stream, when two first order streams join to form a second order stream, when two second order streams join, then it will create a third order stream. Width can be identified by the mean section method.

10. Thiessen polygon method

Three micro watersheds were chosen from the 28 micro watersheds for Theissen polygon method for mean precipitation analysis, namely micro watershed 1(M1), micro watershed 2(M2) and micro watershed 3(M3). These are all located in the beginning of upper most part of the Sathiyar sub basin's micro watershed (Figure 1) and merged into a single polygon like catchment boundary.

The new three Voronoi polygons were created by Thiessen polygon method instead of actual micro watershed boundary. These three rain gauge measuring stations were connected with straight line according to the rules of Delaunay triangles (DiVenere, 1994). Every line was crossed by perpendicular bisector line and this line is extended to both sides with in the Delaunay triangle. Now three separated polygon features were derived with in this area in square kilometres and the mean precipitation value was found to be 3.4 mm. The spatially averaged rainfall or mean areal precipitation is commonly utilized in hydrologic application (Lawrence K. Wang, 2014).The distance between every temporary rain gauge station is measured between the distance of S1 to S2 is 7kms , S2 to S3 is 5kms and S3 to S1 is 4kms.

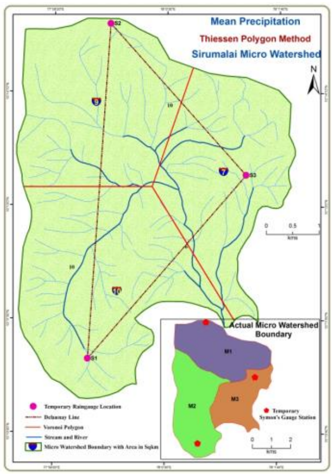

Figure-2: Thiessen polygon method for mean precipitation calculation

Mean Precipitation was measured by the following formula where:

$$\overline{P} = \frac{1}{A}\sum_{i=1}^{N} A_i P_i$$

P stands for the mean precipitation in mm

A_i stands for Area of Thiessen polygon

P_i stands for Rainfall in mm and A $_{is}$ the total area

Table -1: Temporary rain gauge (Symon's gauge) location of harvested land near by water collecting site with amount of rainfall

S.No	Station Name	Rain gauge location (Lat – Lon)	Rain Fall (mm) P_i	Area of the Thiessen polygon (sqkm) A_i
1	S1 (Meenakshipuram)	10°11'25.47"N 77°59'42.513"E	3.4	10
2	S2 (Tollukadu)	10°14'52.154"N 77°59'55.353"E	4	9
3	S3 (Anna Nagar)	10°13'19.109"N 78°1'20.339"E	2.8	7
Total			10.2	26

Based on the formula, the Mean precipitation calculated was 3.4 mm or 0.01 inch.

$$P = \frac{(10 \times 3.4 + 9 \times 4 + 7 \times 2.8)}{26} = 3.4 \text{ mm or } 0.01 \text{ inch}$$

Mean precipitation of actual arithmetic value and Thiessen value are the same i.e. 3.4 mm.

Purpose of the Thiessen method suggests that same amount of rainfall received in any point within the micro watershed area. To apply this rain gauge measured value halfway distance of next station in any direction (Prashant K et al, 2017). Entire study area is covered by 6555 acres and 0.01 inch of rainfall during the study time.

11. Rainfall Intensity

The rainfall intensity (i) was studied at the Sirumalai hill micro watersheds. The rain gauge measurement places were clearly mentioned in the Table 1 and Figure 2. The rainfall measured by using the Symon's gauge (Figure 5.c) technique. Rainfall is measured in millimetre. As per the opinion of Tramblay et al., (2011), the rain gauge was fixed on the ground at a minimum of 10 m radius without any distraction like wind, soil erosion, heavy runoff etc,. All the three rainfall datasets were used at 1-hour time resolution to provide comparable estimates. The precipitation is rarely equal in the entire study area.

12. Landuse and Landcover

Landuse and landcover area is important for CN (Curve Number) calculation. Remote Sensing and GIS techniques were used to prepare the land use map with 30 m resolution of LANDSAT 8 Imagery for 2016 and also it has been referred with 15 m resolution of Google earth and field verifications. Watersheds have land-use information and basin physical characteristics (Curtis Weaver.J 2008).

Table -2: *Landuse classification area with soil Curve Number*

S.No	Land use Description	Actual Area coverage of Micro watershed in Acre (Ai)	CN of Hydrologic Soil Moisture condition (CNi)
1	Dense Forest	5858	70
2	Open	588	71
3	Cultivated Land	77	78
4	Settlement (Grass over > 75%)	22	74
5	Cemetery (Grass over > 75%)	10	74
Total		6555	

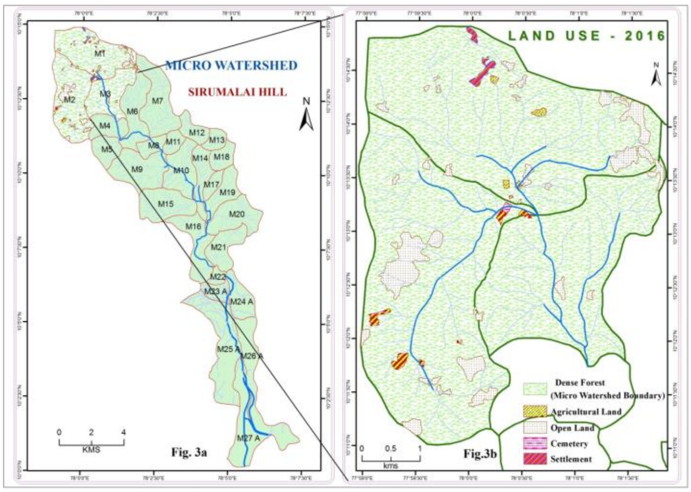

Figure- 3a Micro watersheds of Sirumalai hill catchment area and **Figure- 3b**. Landuse category of three Micro watersheds (M1, M2 and M3)of present study area.

13. Direct Runoff (SCS-CN method)

SCS-CN (USDA Soil Conservation Service) method is simple and widely used method for measuring the direct runoff values in inch from the rainfall. Soulis K.X et al., (2012) used the SCS-CN method for identifying various intensity of rainfall even in heterogeneous watersheds. Since the Sirumalai hill micro watersheds have homogeneous type of geomorphic structure, it is easy to measure the runoff values using the SCS-CN method. Runoff coefficient can be assessed annually, seasonally or monthly depending on purpose of the study. In this study the runoff coefficient

calculated was based on the three days rainfall field measurement (from 10th October 2016 to 12th October 2016). Runoff Curve Number for forest / woodland area is 70 and the potential moisture condition to convert Curve number in dry condition is 0.73 and in wet condition is 1.21 (Source: USDA NRCS, 1984). Soil infiltration and plant interception are equal to the ratio of direct run-off by availability of rainfall (Bhaskar .J and Suribabu .C.R 2014).
Where S is the potential abstraction (related with soil moisture condition)

CN_i is the soil Curve Number based on the soil moisture conditions

RO –Actual runoff (excess rainfall) in inches

P – Precipitation depth, inches

$S = (1000/CN) - 10$

$RO = [(P - 0.2\,S)^2] / (P + 0.8\,S)$ (Bedient & Huber, 1989)

According to the USDA ARS, the soil group is moderate with high runoff potential. It is shallow soil with clay and colloids and with below average infiltration after wetting. Based on the Soil Group Index (GI), value of the study area's hydrologic soil group is C, which has been derived as soil texture of sandy clay loam. Group Index is nothing but consigning the number based on the soil types and its physical properties of size of the particle, liquid limit and plastic limit (Source: US SCS National Engineering Hand Book, Hydrology, USDA ARS).

$$CN_w = \frac{\sum A_i\,CN_i}{AT_i}$$

A_i is Area of Landuse category

CN_i is Soil Curve Number

AT_i is total area

$$CN_w = \frac{(70.5858) + (71.588) + (78.77) + (74.22) + (74.10)}{6555}$$

= 70inch

CN_w value is 70

$S = (1000 / 84.7) - 10 = 1.8$ (Adjustments to Runoff Curve Number in wet condition for Curve Number 70 is multiplied by 1.21 so, the CN value is 84.7)

S value is 1.8

P of rainfall is 3.4 mm or 0.13 inches

$RO = (P - 0.2\,(1.8))^2 / (P + 0.8\,(1.8)) = 0.03$ inch

RO of direct runoff value is 0.03 inch.

14. Runoff Coefficient

Runoff generation is a complex multi-factor process and this method is highly idealized (FHWA, 1986).The runoff coefficient is an area weighted average and the resulting peak runoff is calculated by substituting these values into the rational formula (David A. Chin 2000). According to the Clean Water Treatment (CWT) guidance, the larger areas with permeable soils, flat slopes and dense vegetation should have the lowest "C" values. Similarly, the runoff coefficient of Sirumalai hill micro watersheds of M1, M2 and M3 has 0.23 values.

$$\text{Runoff coefficient (c)} = \frac{\text{Runoff (RO) is } 0.03}{\text{Rainfall intensity (i) is } 0.13} = 0.23$$

In forest area, the runoff coefficient is starting from 0 to 0.25 (Table 3). The result showed that the RO of the Sirumalai hill forest micro watershed area was 0.23 which is the maximum RO value.

15. Rational method

The rational method is used to calculate the quantity of the flow of peak discharge storm water of the drainage area.

The Rational Formula is expressed as follows:

(Q) = c i A

Where: Q = maximum rate of runoff (acre-inches per hour or cubic feet per second (cfs))

c = runoff coefficient representing a ratio of runoff to rainfall (unitless)

i = average rainfall intensity for a duration equal to the Tc (in/hr)

A = drainage area contributing to the design location (acres)

Table-3: Topography and existing Runoff coefficient (c) value.

S.No	Land Cover	% of topography	Runoff Coefficient, c
1	Forest/Woodlands	0 – 7%	0 – 0.25
2	Flat	0 – 2 %	0.05 - 0.10
3	Average	2 % - 7%	0.10 - 0.15
4	Steep	> 7 %	0.15 – 0.25

Adapted from
1. iSWM Design Manual for Development/Redevelopment, 2006
2. City of Austin, Drainage Criteria Manual, 2007

The rational value of Q= c * i * A

= 0.23 * 0.13 inch * 6555 acre

=195.994 inch acre (376.84 acre / hr)

Q is = 1230.97 GPM (Gallon Per Minute)

Accordingly the rational method suggests the runoff water amount is 1230.97 gpm for the three micro watersheds area of 6555 acre. If the rainfall increases, then the amount of surface runoff will also increase.

16. Surface runoff flow rate

Stream flow formation started when the rain fall on a micro watershed connects with the stream line. It is also called as stream segment (Francisco Olivera et al, 2006). The rainfall intensity will vary from the start of the storm and this variation will continue throughout the storm because some amount of volume of water will be infiltrated during the first 8 hours (Horton's Infiltration Model, 1933). The runoff computations are calculated during the wetted condition. If the earth surface is moisturised by earlier rainfall, then it becomes wetted and free flow of runoff water can flow without any interception like soil infiltration. Long-term records of flow data are essential to certify for the up to date measurement of surface water and also ground water resource (WMO, 2012). The runoff equation was developed for this condition. By doing the bucket method, some soil or litter particles may be omitted. The collection of runoff value measurement was shown in the Table 4. After the initial demands of interception and infiltration, the surface flow has been identified. As the study of Santillan et al., (2010) suggests, the runoff is high in Siumalai during the period of rainfall because the channel flow occurs among the forest area. The entire field observation and water collection should be pre-planned to identify the vegetated channels and diversions in order to avoid major environmental turbulence if any.

17. Time of concentration (Tc) of Channel flow

If the storm water flow is free to travel in open channel without any interception it is known as channelized flow (Pilgrim et al., 2009). It is also known as Time of concentration (Tc). It could be measured in three places of the study area namely M1, M2 and M3 micro watersheds. The time of concentration is used to measure the time taken for flow speed on the watershed (Argue John, 1987).

Three types of flow methods are available to calculate the time of concentration. They are channel flow or storm drain flow, Sheet Flow and Shallow Concentrated Flow. Appropriate value of hydraulic radius estimated in channel flow concentration (Jonathan Green and James Nelson, 2002) is followed to find the time of concentration. Number of empirical equations is developed for time of concentration method for various type of watersheds. They are Izzard equation, the Kerby equation, the Kirpich equation, the Manning equation etc.

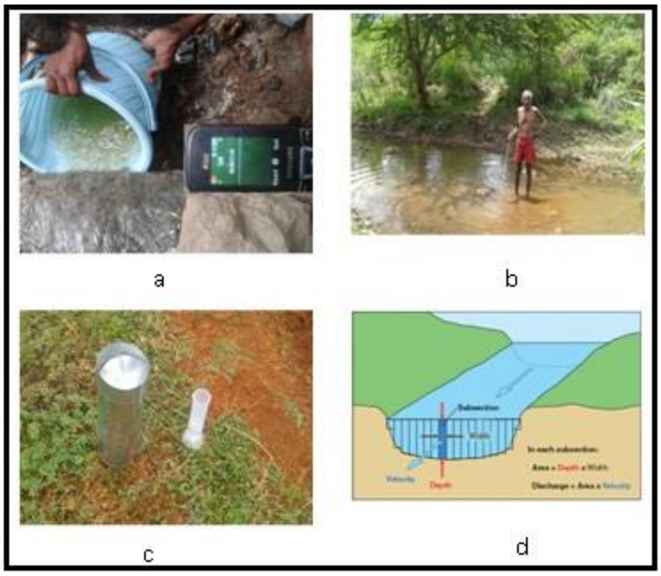

Figure-5*:* Physical mechanism of Rainfall and surface runoff measuring techniques in stream area. a. Bucket method of runoff volumetric flow rate measuring (at 10°11'26.04"N 77°59'40.45"E), b. Stream flow depth measuring, c. Rainfall measured by Symon's raingauge and d. Stream area and discharge velocity measuring process (See Table 5).

Manning's equation was used in this study for identifying channel flow concentration (USDT – FHA, 1984). It is just like the open channel flow rate assessment. Time of concentration is surface water runoff measurement during the rain fall event response within the watershed area. That is defined as the time required for water to flow from the most hydraulically (David, 2006) distant part to the watershed outlet (Haan et al., 1994).

Table-4: Volumetric measurement of flow rate by bucket method it's time of filling in seconds

M1: Rainfall 3.4mm/hr Length of stream: 1053 ft			M2: Rainfall 4mm/hr Length of stream: 601 ft			M3: Rainfall 2.8mm/hr Length of stream: 788 ft		
S.No	Time in Seconds	Volume of water in litre	S.No	Time in Seconds	Volume of water in litre	S.No	Time in Seconds	Volume of water in litre
1	20	6	1	15.32	8	1	25.7	5
2	15.6	6	2	13.13	8	2	23.4	5
3	19.5	6	3	17.2	8	3	26	5
4	20.4	6	4	12.4	8	4	24.5	5
5	14.36	6	5	13.63	8	5	28	5
6	16.75	6	6	11.85	8	6	20	5
7	18.31	6	7	10.71	8	7	21	5
8	15.42	6	8	12.35	8	8	23.4	5
9	12.9	6	9	10.76	8	9	21.6	5
10	18.65	6	10	9.22	8	10	27	5
Average	17	6 litre or 0.5961 ft		13	8 litre or 0.6562 ft		24	5 litre or 0.5609 ft

Flow velocity and travel time are relatively sensitive to the exact flow depth but flow velocity always varies because of the friction along the channel boundary (CIVE, 2400). Due to time of concentration measurement, even if rain fall occurred in part of the study area, the amount of water and the travelling time to reach the storage place can be calculated. The effective runoff flow propagation is contributed to the flood forecasting in response to land cover and climate variability (Dennis et al., 2016). The Time of concentration of channel flow formula derived for total number of micro watersheds is:

$Tc = T_{T1} + T_{T2} + T_{T3.}$

Computation of Travel Time for the channel is done through the formula:

$$T_T = \frac{L}{3600\ V}$$

Where :

Tt = travel time (hr), L = flow length (ft), V = Average velocity (ft/s) and 3600 = conversion factor from seconds to hours.

$$T_{T1} = \frac{1053\ ft}{3600\ (0.5961\ ft/sec)} \quad \text{then } T_{T1} = 0.49 \text{ hours}$$

$$T_{T2} = \frac{601\ ft}{3600\ (0.6562\ ft/sec)} \quad \text{then } T_{T2} = 0.25 \text{ hours}$$

$$T_{T3} = \frac{788\ ft}{3600\ (0.5609\ ft/sec)} \quad \text{then } T_{T3} = 0.39 \text{ hours}$$

Tc = 0.49 + 0.25 + 0.39 then

Tc = 1.13 hours (Total time of concentration for 6555 acre).

David B. Thompson (2006) explains that the Time Concentration should be less than 300 minutes (5 hours) and greater than 10 minutes. In the same way, the Tc of the current study is 1.13 hours which is an accepted value. The estimate time of concentration can be more relevant than the influence of CN and catchment characteristics like slope, flow path, distance etc (USDA-NRCS -2010).

18. Direct Discharge measurement of Area-velocity method

Figure 5.d shows the discharge measurement of the actual runoff rate which is commonly expressed in cubic metres per second (m^3/s or cumec). The depth for each vertical cross section was measured (Jesse Hickey, 2011). Each subsection of a channel cross section and summing the subsection discharges to obtain a total discharge (Apollov et al, 1974).

The wetted or even saturated channel / stream runoff will rush over a next connecting point channel and was not further reduced on its way downstream (Jens Lange and Chris Leibundgut, 2000). In each subsection of the cross sectional stream area, the Discharge velocity value was averaged by it's time, so the calculated average value of depth of the stream segment (y) is 0.3 m, (Table 5) mean while the width of the circled same stream's upper most or over flowing part in between the banks can be measured (see figure 5.d).

Table- 5: Stream segment or cross sectional area of stream order

Segment	Depth / Height of stream in meter
	I st Order (10°11'26.04"N 77°59'40.45"E)
1	0.2
2	0.3
3	0.5
4	0.3
5	0.2
Average	**0.3**
	Width/Breadth of stream in meter
	1.6

Discharge velocity is derived as:
Q = A * v
Area (a) = width (b) * depth (y)
Discharge (D) = Area * Flow Velocity (V)
(The flow velocity is divided by time. Volumetric flow rate of rainfall is 6 litre/17 sec. or 0.07 m (Ref.Table:4)
Area = 1.6 m * 0.3 m
A is 0.48 m^2
Discharge = 0.48m^2 * 0.35 litre/sec
D = 5.16 ft^2 * 0.23 ft/sec
= 1.17 ft^3/sec or 8.7 gal/sec
= 522 GPM.
Discharge velocity is not equal to actual velocity based on the physiographic features.
This calculation of the study showed the values of the three watersheds of Sirumalai Hill environs as below:
The total area of the three micro watersheds is 6555 acre and the rational value is 1230.97 GPM; The single stream area is 0.48 m^2 with discharge velocity of 522 GPM; and the time of concentration was 1.13 hr to reach into the outlet of particular micro watershed (78°1'7.434"E 10°11'45.449"N) location.

19. CONCLUSIONS

Multiple hydrologic analyses of Thiessen polygon, SCS-CN method, Runoff coefficient, and rational method, Time of concentration and area velocity methods were used for identifying the quantity of surface runoff water and these results can be used to create a flood modelling. The calculated amount of water which will approximately reach the Sathiyar reservoir during 3.91 hours of travel through the fifth order stream with the distance of 17806 m or 17.8 km, excluding other environmental factors such as direct precipitation, additional runoff from another micro watershed, slope, vegetation interception and etc., is 1230.97 GPM. Close observation of the results of the hydrologic computational methods and models determined the flow rate and quantification of water level during the monsoon period. The catchment area water is sufficient for the cultivating area but the cultivation is occurring in minimum three to maximum seven month duration, cultivated plants need more water in regular intervals. In this situation reservoir is facing loss of water in many ways of natural processes such as evaporation, evapotranspiration, infiltration, seepage etc.

This present mathematical calculations clearly depict the necessity of the recirculation of the surface water estimation in the Sirumalai hill environs for agricultural purposes. The Public Works Department, Sathaiyar Reservoir area, explained that the depth of reservoir was 29 ft in 1965 and it is gradually reduced to 17 ft now in 2016 due to 10 ft of dead storage and 2 ft of semisolid because this reservoir was not desilted after 1965. The PWD has submitted a plan to the Tourism Department for desiltation in 2012. But the plan is yet to be fulfilled. This is the main reason for reduction of water storage level. If proper drainage system maintenance and increasing the reservoir holding capacity by desiltation have been done, the minimizing the shortage of water for irrigation and ground water table improvement in this region throughout year can be possible. The present study is satisfied in showing the possibility of runoff estimation by rainfall measurement of onsite field work. If we establish an automated measurement of other environmental factors, then it will be easy to calculate the flood level.

REFERENCES

[1] Apollov B.A., Kalinin G.P., Komarov V.D (1974). Course of hydrological forecasting 420 pp.

[2] Argue John R (1987). Storm Drainage Design in Small Urban Catchments, A Hand Book for Australian Practice, Australian Road Research Board, Special Report No.34.

[3] Arved J.Raudkivi (1979), An advanced introduction to Hydrological processes and modelling, Hydrology. Pergamon press, . pp 90

[4] Barry, R. G., and R. J. Chorley, 1987: Atmosphere, Weather and Climate. 5th ed. Methuen, 460 pp.

[5] Bedient, P.B and W.C. Huber (1989). Hydrology and Flood plain Analysis. Addison Wesley Publishers, Reading, MA.

[6] Bhaskar .J and Suribabu .C.R, (2014) Estimation of Surface Run-off for Urban Area Using Integrated Remote Sensing and GIS Approach. Jordan Journal of Civil Engineering, Volume 8, No. 1.

[7] CIVE 2400, Fluid mechanic, Section 2: Open Channel Hydraulics, pp 9.

[8] Clean Water Team (CWT) Guidance Compendium for Watershed Monitoring and Assessment State Water Resources Control Board SOP-5.1.2 (Runoff Vol) 8-31-10 AT.

[9] Curtis Weaver.J. Methods for Estimating Peak Discharges and Unit Hydrographs for Streams in the City of Charlotte and Mecklenburg County, North Carolina. U.S.G.S - 2008, Water-Resources Investigations Report 03–4108, pp 1.

[10] Darbral .P.P, Pandey P.K, Tushar Kumar and Sorav Chakraborty (2014), Determination of Discharge Coefficient and Head-Discharge Relationships of Different Hydraulic Structures.

[11] Journal of Indian Water Resources Society, Vol 34, No.1. pp 40.

[12] David A. Chin. Water-resources Engineering, Prentice Hall, 2000 - Technology & Engineering - 360pp.

[13] David B. Thompson (2006), The Rational Method. Engineering Hydrology, Texas USA.

[14] Dennis W. Hallema, Roger Moussa, Ge Sun and Steven G. McNulty, Surface storm flow prediction on hillslopes based on topography and hydrologic connectivity. Ecological Processes 20165:13. DOI: 10.1186/s13717-016-0057-1, September 2016.

[15] DiVenere V.J. GLY 15 / GLY 518 - Groundwater Geology - LIU Post.

[16] Federal Highway Administration (FHWA 1986). RailRoad-Highway Grade crossing Handbook, Second Edition, FHWA-TS-86-215.U.S. Department of Transportation,

[17] Francisco Olivera, Srikanth Koka and James Nelson (2006). WaterNet: A GIS Application for the Analysis of Hydrologic Networks Using Vector Spatial Data. Transactions in GIS, 2006, 10(3): 355–375.

[18] Haan C.T. , B.J. Barfield, J.C. Hayes, 1994, Design Hydrology and Sedimentology for Small Catchments, Academic Press; Reprint edition (1994). ISBN-13: 978-0123123404, pp 29 - 30.

[19] Harlan Bengtson. Calculating Watershed Time of Concentration. Bright Hub Engineering, 2010.

[20] JENS LANGE & CHRIS LEIBUNDGUT (2000), Non-calibrated arid zone rainfall-runoff modelling. The Hydrology-Geomorphology Interface: Rainfall. Floods, Sedimentation, Land Use (Proceedings of the Jerusalem Conference, May 1999). IAHS Publ. no. 261.

[21] Jesse Hickey 2011. Compared to the USGS Cherry Creek Gaging-Station Denver, CO. Accuracy of the Cross Section Method of Determining Stream Discharge with Variance in Current Meter Selection and Number of Vertical Sections.

[22] Jonathan I. Green and E. James Nelson (2002), Calculation of time of concentration for hydrologic design and analysis using geographic information system vector Objects. Journal of Hydroinformatics . 04.2. pp 80.

[23] Kite.G.W and Pietroniro.A (1996), Remote sensing applications in hydrological modelling .Hydrological Sciences -Journal- des Sciences Hydmlogiques,tt(4), pp 564.

[24] Kuichling, E. (1889). The relation between the rainfall and the discharge of sewers in

[25] populous districts. Transactions, American Society of Civil Engineers 20, 1–56.

[26] L. Lanza, M. Leroy, C. Alexandropoulos, L. Stagi and W. Wauben (2005), Laboratory Intercomparison of Rainfall Intensity Gauges. Instruments and observing methods, (WMO) world meteorological organization. report no. 84. 4 pp.

[27] Lawrence K. Wang (2014), Modern Water Reource Engineering, Handbook of Environmental Engineering, Vol-15, Humana Press, USA.

[28] Millán.M.M, Estrela.J, and Miró.J (2005), Rainfall Components: Variability and Spatial Distribution in a Mediterranean Area (Valencia Region). Journal Of Climate vol- 18. 2687 pp.

[29] Meteorological Office, 1962: General Meteorology. Vol. 1, Weather in the Mediterranean, 2d ed. Her Majesty's Stationary Office, 362 pp.

[30] NJSBM (New Jersey Stormwater Best Management Practices Manual) • Chapter 5: Computing Stormwater Runoff Rates and Volumes • February 2004 • Page 5-27.

[31] Pilgrim D.H., Chapman T.G., Doran D.G.(2009): Problems of rainfall-runoff modelling in arid and semiarid regions. Hydrol. Sci. J. 33(4), 379–400. DOI: 10.1080/02626668809491261.

[32] Prashant K. Srivastava, Prem Chandra Pandey, Pavan Kumar, Akhilesh Singh Raghubanshi, Dawei Han (2017), Geospatial Technology for Water Resource Applications. CRC Press, Taylor and Francis Group, A Science Publishers Book. pp 50.

[33] Santillan.J.R, Makinano. M.M and Paringit.E.C (2010), Intergrating Remote sensing, GIS and hydrologic models for predicting land cover change impacts on surface runoff and sediment yield in a critical watershed in Mindano, Philippines. International Archives of the Photogrammetry, Remote sensing and spatial information Science, VOlume XXXVIII, Part 8, Kyoto, Japan.

[34] Slobodan P. Simonovic. Managing Water Resources,. Methods and Tools for a Systems Approach. Earthscan in the UK and USA in 2009.pp 70.

[35] Stormwater Management Design Manual (SMDM).Revised: Oct. 1, 2007, July 1, 2014.

[36] Tramblay.Y, Bouvier .C, Ayral P.A and Marchandise.A (2011), Impact of rainfall spatial distribution on rainfall-runoff modelling efficiency and initial soil moisture conditions estimation. Nat. Hazards Earth Syst. Sci., 11, 157–170, doi:10.5194/nhess-11-157-2011.

[37] Trimmer .W.L (1994), Estimating Water Flow Rates. Oregon State University Extension Service offers educational programs, activities, and materials.Reprinted September 1994.

[38] USDT - FHA (U.S.Department of Transformation - Federal Highway Administration) (1984), Guide For Selecting Manning's Roughness Coefficients For Natural Channels And Flood Plains, Report No.FHWA-TS-84-204.

[39] USDA United State Development of Agriculture, Natural Resources Conservation Service (NRCS - 1984).

[40] (USDA-NRCS) Department of Agriculture, Natural Resources Conservation Service. Time of Concentration Part 630 Hydrology, National Engineering Handbook Chapter 15 (210–VI–NEH, May 2010). Pp 15–3.

[41] World Meteorological Organization (WMO), (2012) Technical Material For Water Resources Assessment Technical Report Series No. 2.WMO-No. 1095. 2 pp.

[42] Yu. B. Vinogradov, Runoff generation and storage in watershed. Hydrological Cycle - Vol.III. Encyclopdia of Life Support Systems(ELOSS).

[43] https://en.wikipedia.org/wiki/Rain_gauge